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(54) Multi-chip module and process of forming it

Multichip-Modul und Verfahren zu seiner Herstellung

Module multi-puce et procédé de sa fabrication

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- **IBM TECHNICAL DISCLOSURE BULLETIN vol. 21, no. 5, October 1978, NEW YORK pages 1895 - 1897 S. MAGDO 'low inductance module'**
- **IBM TECHNICAL DISCLOSURE BULLETIN vol. 27, no. 6, November 1984, NEW YORK pages 3335 - 3336 L.S. GOLDMANN 'universal electronic package'**

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Description

The present invention relates generally to packaging of semiconductor devices and specifically to a design of chip carriers that facilitates the manufacture of semiconductor devices. More particularly, the invention relates to a multi-chip module and to a process for forming a multi-chip module.

Several prior art methods exist for manufacturing semiconductor devices in packages. FIG. 9 is a flow chart illustrating the prior art of manufacturing multi-chip modules using a deposition method (MCM-D). In this method, layers of a substrate are built sequentially one on top of another. After each layer is built, each layer is tested. In a manner well known in the art, a power substrate is first built (step 1001). After manufacture, the power substrate is tested (step 1002). The next layer, a thin film substrate 1 (TFS1), is deposited on the top surface of the power substrate in a manner well known in the art (step 1003). The partially assembled substrate is tested (step 1004). If the partially assembled substrate fails the test, it must be either reworked or discarded. In the latter alternative, a good power substrate is discarded as part of the failed partially assembled substrate. A second thin film substrate (TFS2) is deposited on the first thin film substrate (TFS1) (step 1005) and tested (step 1006). As with the first thin film substrate, the entire partially assembled substrate must be reworked or discarded if it fails the test at step 1006. This process is continued until the Nth layer of the thin film substrate (TFSN) is deposited on the sequentially assembled substrate (step 1007) and tested (step 1008). Parallel to the assembly of the substrate, the chip is assembled (step 1009) and tested (step 1011). After the substrate is assembled and successfully tested, the successfully tested chip is attached to the substrate using a chip attachment technique which is well known in the art (step 1012).

This MCM-D assembly process allows high density interconnections because the deposition process uses standard photolithography techniques which provide small signal traces, small intertrace distances, and close alignment between successive substrate layers. However, this method has several drawbacks. First, a layer requiring a higher annealing temperature must be manufactured before layers requiring lower annealing temperatures thereby imposing potentially severe limitations upon the design and packaging of the semiconductor devices. For example, a thin film capacitor layer made from tantalum pentoxide (Ta_2O_5) is annealed at temperatures between 600° and 800° centigrade for approximately one minute. The other substrate layers are typically made of other dielectrics which typically have lower stability temperatures. For example, one typical material is polyimide which is stable up to 400° centigrade. Thus, the thin film capacitor layer must be made before the polyimide layers and consequently the capacitor layer cannot be the top layer. For some electrical

circuits, it is desirable that the capacitor layer be as close to the chip as possible. In this instance, the physical limitations of the substrate limit the electrical performance of the corresponding circuit.

Second, sequentially building the layers using an MCM-D method also provides low overall yields. For example, if one layer has a manufacturing yield of 90% and a second layer has a manufacturing yield of 90% the average overall yield of manufacturing the two layers is 81%. As the number of layers increases, the overall yield correspondingly decreases. In some designs, one module layer may have a yield on the order of 50%. If this layer is built at a later stage, a large number of good partially assembled layers are discarded after the low yield layer is added. Thus, to reduce the manufacturing costs, low yield layers are typically designed to be one of the first manufactured layers. This places additional constraints on the electrical design of the semiconductor device and package.

FIG. 10 is a flow chart illustrating the prior art of fabricating a multi-chip module using a laminated method (MCM-L). Unlike the MCM-D method, the MCM-L method manufactures layers in parallel. The first through the Nth thin film substrates (TSF1...TSFN) are manufactured in parallel (steps 1101, 1102, 1103). In addition, the power substrate is also manufactured in parallel (step 1104). Each substrate layer is subsequently individually tested (steps 1106, 1107, 1108, 1109). After successfully passing testing, the substrate layer is stripped from the thin film substrates to form a thin layer of deposited material containing interconnection traces and vias (steps 1111, 1112, 1113). The thin layers are then combined with the power substrate to form the substrate layer (step 1114). This combination requires an interconnection contact on one substrate layer to be electrically connected to a corresponding bond pad on another substrate layer. To laminate the layers together, the layers are lined up so that the bond pads are opposite each other in spaced apart relation. A bonding material such as epoxy is placed between the substrate layers and cured to provide a rigid mechanical structure. To connect the spaced apart bond pads, the rigid structure is drilled to form a bore that extends through the electrical conductors that are to be connected from one surface of the rigid structure to another surface on the opposite side of the rigid structure (step 1116). The bores are then metallized by plating or other processes known in the art to thereby provide an electrical path between the bond pads on separate substrate layers (step 1117). In a manner similar to that described above in FIG. 9, the chips are assembled (step 1118) and tested (step 1119). Chips passing the electrical test are then coupled to the carrier (step 1120).

The MCM-L method has many drawbacks. First, the stripped thin film substrate layers are thin and flexible so that when the substrate layers are handled while placing them in spaced apart relation, the layers tend to warp. The warping causes corresponding bond pads to

become misaligned. Second, the process of placing bonding material between substrate layers limits the minimum thickness of the assembled substrate. Third, the rigid mechanical structure is mechanically drilled. Mechanical drill bits have a smallest diameter of about 150 microns. This limits the pitch between the electrical conductors in the substrate.

If a semiconductor device can be divided into separate layers that are capable of being manufactured and tested individually, drawbacks including those identified above are circumvented. For example, two layers requiring different annealing temperatures can be manufactured individually and then combined into a final product. Moreover, as devices are formed by combining only those layers which have already been tested, overall yield will be limited only by the yield of the assembling step, and should thus be even higher than 90%.

Furthermore, as individual layers are manufactured and tested in parallel, manufacturing time of a device is shortened.

EP-A-0 268 111 discloses the use of a chip interposer which is inserted between a semiconductor device and a substrate. The interposer comprises conductive vias and multiple wiring planes which are selectively connected to the vias, and accommodates a discrete capacitor on its top surface alongside the semiconductor device. However, the interposer does not have formed within it any components such as resistors or capacitors, and does not exhibit layers having different types of components formed within them.

EP-A-0 414 204 discloses a multilayer interconnection substrate for a plurality of semiconductor chips, the substrate including signal layers, power supply layers and power supply matching layers which are sintered together. Again, the interposer does not have formed within it any components such as resistors or capacitors, and does not exhibit layers having different types of components formed within them.

IBM Technical Disclosure Bulletin, Vol. 27, No. 6, November 1984, discloses a universal electronic package in which thin ceramic layers are stacked and interconnected by using thin copper "hat pins". Discrete components can be mounted at either side of any of the ceramic layers, but components are not formed within the layers.

IBM Technical Disclosure Bulletin, Vol. 21, No. 5, October 1978, discloses a low inductance multilayer ceramic module formed by ceramic layers having vias for supplying power to a chip.

EP-A-0 379 404 discloses a multilayer hybrid circuit comprising a semiconductor chip mounted to a laminated body comprising a plurality of dielectric layers, magnetic layers and conductive patterns, composing a capacitor, an inductor, and a resistor. However, there is no disclosure of providing different, single types of functional elements within respective stacked substrates.

According to a first aspect of the present invention, there is provided a multi-chip module, comprising:

a multi-layer interconnection substrate carrying a plurality of integrated circuit elements disposed thereon, wherein the multi-layer interconnection substrate comprises a plurality of interconnection traces to communicate electrical signals between said integrated circuit elements, where each integrated circuit element comprises:

a first functional substrate having a bottom and a top interconnect layer, the bottom interconnect layer being coupled to the interconnection substrate, said first functional substrate having a single type of passive electrical functional elements; and

at least one second functional substrate stacked successively on said first functional substrate, each having a bottom and a top interconnect layer, the lowermost second functional substrate having its bottom interconnect layer coupled to the top interconnect layer of said first functional substrate, and the uppermost second functional substrate having its top interconnect layer coupled to at least one semiconductor chip, each second functional substrate having a single type of passive electrical functional elements, and wherein integrated circuits of the semiconductor chip are in electrical contact with the passive electrical functional elements of the first and each second functional substrate;

wherein the passive electrical functional elements in the first and each second functional substrate are selected from the group consisting of electrical signal conductors, capacitors, and resistors;

wherein the top and bottom interconnect layers of the first and each second functional substrate have identical patterns of electrical contacts; and wherein the first and second functional substrates each comprise through-hole connectors extending therethrough that are filled with conductive vias, the conductive vias interconnecting the top and bottom interconnect layers of the first and each second functional substrate and providing connection with the passive electrical functional element within the first and each second functional substrate.

According to a second aspect of the present invention, there is provided a process for forming a multi-chip module comprising the steps of:

forming a multi-layer interconnection substrate for carrying a plurality of integrated circuit elements, the interconnection substrate having a top interconnect layer, and having a plurality of interconnection traces to communicate electrical signals between said integrated circuit elements;

forming each integrated circuit element by:

forming a first functional substrate having a single type of passive electrical functional elements, the first functional substrate having a bottom and a top interconnect layer;
 forming at least one second functional substrate each having a single type of passive electrical functional elements, each second functional substrate having a bottom and a top interconnect layer, wherein the top and bottom interconnect layers for the first and second functional substrates are formed by using the same metallurgy, design rules, and fabrication processes, wherein each first and second functional substrate comprises through-hole connectors extending therethrough that are filled with conductive vias, the conductive vias interconnecting the top and bottom interconnect layers of the first and each second substrate and providing connection between the passive electrical functional elements in the first and each second substrate, wherein the top and bottom interconnect layer for the first and each second substrate have identical patterns of electrical contacts, and wherein the passive electrical functional elements in the first and each second substrate are selected from the group consisting of electrical signal conductors, capacitors, and resistors;
 stacking one said second functional substrate on said first substrate so that the electrical contacts of the bottom interconnect layer of one said second functional substrate are connected with the electrical contacts of the top interconnect layer of the first functional substrate; and
 stacking a semiconductor chip on one said second functional substrate so that the chip is connected to the electrical contacts of the top interconnect layer of one said second functional substrate;

mounting the first functional substrate onto the interconnection substrate so that the electrical contacts of the bottom interconnect layer of the first functional substrate is connected to electrical contacts of the top interconnect layer of the interconnection substrate, wherein the first and second functional substrates are formed separately and tested before being stacked together and mounted onto the interconnection substrate.

Reference is made, by way of example, to the accompanying drawings in which:

FIG. 1 shows schematically a cross-sectional illustration of a semiconductor device useful for understanding the invention.

FIG. 2 shows schematically a cross-sectional illustration of the semiconductor device of FIG. 1 with the substrates separated.

FIG. 3 shows schematically a cross-sectional illustration of the general structure of a substrate as shown in FIG. 1.

Figs. 4a and 4b show schematically another semiconductor device useful for understanding the invention.

FIG. 4c is an alternate schematic illustration of how the circuit of FIG. 4a is formed in the structure of FIG. 4b.

FIG. 4d is a cross sectional view of a device in which the capacitor substrate 419 and the resistor substrate 420 are interchanged from that of the device shown in FIG. 4b.

FIG. 4e is an alternate schematic illustration of the structure of FIG. 4d to more clearly show how the circuit 400 of FIG. 4a is formed by the structure of FIG. 4d.

FIG. 5 is a flow chart illustrating how the present invention can accelerate manufacturing of a semiconductor device.

FIG. 6 illustrates schematically a plan view of an exemplary pattern of contacts in each of the top and bottom interconnection layers.

FIG. 7 is a top plan view showing a fully populated multi-chip module (MCM) according to principles of the invention.

FIG. 8 is a schematic cross-sectional view of the MCM taken along line 9-9 of FIG. 7 showing integrated circuit elements constructed according to principles of the invention.

FIG. 9 is a flow chart illustrating the prior art of manufacturing multi-chip modules using a deposition method (MCM-D).

FIG. 10 is a flow chart illustrating the prior art of fabricating a multi-chip module using a laminated method (MCM-L).

A feature of this invention is the creation of a carrier for integrated circuit chips from a plurality of interconnected substrates. Four types of substrates are employed in a typical circuit. Each substrate has an identical pattern of bonding pads on each face. The substrates in an exemplary carrier are bonded together face-to-face by way of the bonding pads. Circuits are assembled by electrical connections through and between the substrates.

An interconnection substrate has an identical pattern of bond pads on its top and bottom faces. In an exemplary interconnection substrate some of the bond pads on one face are connected directly to opposite bond pads on the other face. Some of the bond pads on the top face may be connected to bond pads on the bottom face which are not opposite. Thin film conductors in the interconnection substrate interconnect such non-opposite bond pads. Some of the bond pads may not be connected to anything in a specific embodiment. The interconnections within a specific interconnection substrate are produced for a specific circuit configuration.

Another type of substrate is a capacitor substrate. It also has identical patterns of bond pads on its top and bottom faces. Some of these bond pads are connected to terminals of thin film capacitors built into the capacitor

substrate. Which pads are connected to capacitors of specific values is a feature of the circuit in which the capacitor substrate is to be used.

A third type of substrate is the resistor substrate. It, too, has identical patterns of bond pads on its top and bottom faces. Thin film resistors are formed within the substrate. Such resistors are connected to bond pads in an arrangement suitable for a specific circuit to be assembled from such substrates.

The final common type of substrate is a power supply substrate. It has a pattern of bond pads on its top face identical to the bond pad pattern on the other substrates. Functional circuit elements such as ground connections or power supplies are formed in the power supply substrate.

This permits, for example, a substrate with resistors to be fabricated and tested without regard for the other circuit elements to be connected to it.

A collection of such substrates are then assembled in a face-to-face stack with the bond pads on adjacent substrates being bonded together. Typically an interconnection substrate is at the top of the stack. Integrated circuit chips are mounted on the interconnection substrate with the chip leads being connected to selected bond pads on the bottom of the substrate, either directly through the substrate or to more remote pads by way of interconnecting leads built into the substrate.

A power supply substrate is usually the bottom of the stack for heat dissipation. In between are resistor substrates and capacitor substrates sandwiched face-to-face.

Circuits are "assembled" by way of connections in the various substrates to interconnect active circuit element leads with capacitors, resistors, ground, etc. as required. This can be contrasted to assembling the circuit by connecting the active elements to discrete components such as capacitors, resistors, etc. It also can be contrasted with devices made where separate capacitor, resistor and active circuit element layers are sequentially formed on a single substrate. The separate substrates can be manufactured separately in the most cost effective way and each substrate is tested before it is put into the assembled device.

In effect, the assembly of substrates resembles an integrated circuit where the active components (e.g. transistors), capacitors and resistors are all formed and interconnected on a single substrate with successive thin film layers. It differs in that the connections between adjacent layers are by feedthroughs or vias extending through the respective substrates since the layers themselves are on different substrates. It also differs in that the integrated circuit chips are secured to an interconnection substrate or directly to a functional substrate instead of being integral with the substrate. This enables the interconnection of numerous chips on a substrate. Signal transit times remain short since the functional substrates are thin.

FIG. 1 shows schematically a cross-sectional view

of a semiconductor device 100 useful for understanding the present invention, but not in accordance therewith. The semiconductor device 100 comprises a chip carrier 101 having a plurality of functional substrates, such as a power supply substrate 102, a thin film resistor substrate 103, a thin film capacitor substrate 104, and a signal connection substrate 105. As will be described below, each functional substrate is electrically and physically coupled to substrates adjacent to its top and bottom surfaces.

The functional substrates 102, 103, 104, 105 need not be arranged as shown in FIG. 1, but can in general be arranged in other configurations and sequences, depending upon the requirements of a particular device.

A plurality of semiconductor chips 106 are electrically coupled to the top surface of the top functional substrate. As shown in FIG. 1, the chips 106 are attached to the signal connection substrate 105.

FIG. 2 is a schematic cross-sectional view of the semiconductor device 100 showing the substrates 102, 103, 104, 105 separated. As shown, each of these substrates, with the exception of the power supply substrate 102, has a top interconnect layer 201 and a bottom interconnect layer 202 for electrically communicating with a respective bottom interconnect layer 201 and a top interconnect layer 202 of an adjacent functional substrate.

The power supply substrate 102 is shown to have only a top interconnect layer. This is because power supply circuits are typically placed at the bottom of a semiconductor device to facilitate heat dissipation. If needed, the power supply substrate 102 can also have both a top and a bottom interconnect layer similar to the resistor substrate or the capacitor substrate.

The general structure of each of the substrates 102, 103, 104 and 105 is shown in more detail in the cross-sectional view of FIG. 3. Each of these substrates has a plurality of predetermined functional elements formed in one or more thin film layers 302 on top of a wafer 301. The relative dimensions of features shown in FIG. 3 are exaggerated to facilitate illustration thereof.

For a capacitor substrate 104, a plurality of capacitors is formed within the thin film layers 302. An exemplary structure of a thin film capacitor can be found on pages 19-3 and 19-28 of Handbook of Thin Film Technology, by Leon I. Maissel and Reinhard Glang; McGraw-Hill Publishing Company; 1983 Reissue. The capacitors can be used, for example, as bypass capacitors by circuits within the semiconductor chip(s) 106 to be coupled to the chip carrier 101.

For a resistor substrate 103, a plurality of resistors is formed in the thin film layer 302. An exemplary structure of a thin film resistor can be found on page 18-35 of Maissel, et al. The resistors can be used, for example, as terminating resistors or pull-up resistors by circuits within the semiconductor chip(s) 106 to be coupled to the chip carrier 101.

Referring again to FIG. 3, a top interconnect layer

303 is formed on top of the thin film layer 302 of each of the substrates 102, 103, 104, 105. A bottom interconnect layer 304 is formed on the bottom of the wafer 301 of each of the substrates 102, 103, 104. One such interconnection is found in Rao R. Tummala and Eugene J. Rymaszewski, Microelectronics Packaging Handbook, chapter 6, p. 366, Van Norstrand Reinhold, New York, 1989. The top interconnect layer 303 and the bottom interconnect layer 304 each have substantially identical bond pads 306 on the top and bottom surfaces, respectively. The plurality of bond pads 306 on the top interconnect layer 303 and the bottom interconnect layer 304 are arranged in identical patterns to each other so that the top interconnect layer 303 of any substrate may be electrically and physically coupled to the bottom interconnect layer 304 of any other substrate. As will be described below in connection with FIG. 4, the identical pattern allows the substrates to be interchanged. In addition, the interconnect layers 303, 304 are formed using the same metallurgy, the same design rules, and the same fabrication processes for each layer. Consequently, once the substrates are formed, the interconnect layers 303, 304 are formed using the same process. Furthermore, the physical structures of the interconnect layers 303, 304 are identical. Because of this identity, when the layers are electrically connected together, a uniform force may be applied across the surfaces of the layers to achieve electrical contact. The bond pads can be deformable bumps or other electrical connectors made of such materials such as solder, conductive elastomer or gold.

To connect the functional elements within a substrate to the bottom interconnect layer 304 or to connect the top interconnect layer 303 to the bottom interconnect layer 304, intra-substrate connections such as through-hole connectors 305 are formed in the wafer 301 of each substrate. The through-hole connections can be formed using known techniques such as drilling, reactive ion etching or plasma etching to form a hole (see supra page 4, line 29 of the article by Tummala, et al.). The holes are then filled with conductive metal. The conductive material selected to fill or metallize the through-hole may include metals, alloys of metal or metal-nonmetal compositions. The through-hole may be metallized by using deposition techniques well known to those skilled in the art such as chemical vapor deposition, plasma deposition, electroplating or metal organic chemical vapor deposition.

The power supply substrate 102 has power supply circuits formed on a wafer 301. The power supply substrate has a top interconnect layer 303, but no bottom interconnect layer 304, because the power supply substrate 102 is typically placed at the bottom of a semiconductor device. In general, however, a bottom interconnect layer can be provided as in the other functional substrates if required by a particular design.

The above-described substrates can be manufactured and tested individually and separately as de-

scribed below in conjunction with FIG. 5. After they have been tested, two or more substrates can then be bonded together (e.g., by solder) to form a semiconductor device.

Another semiconductor device which is useful for understanding the invention, but not in accordance therewith, is illustrated in FIGs. 4a and 4b.

FIG. 4a is a schematic circuit diagram of a device 400 which comprises a field effect transistor 401 having a drain terminal 402, a source terminal 403, and a gate terminal 404. The gate terminal 404 is connected through a resistor 405 to a power supply VCC to which the source terminal 402 is also connected. The gate terminal 404 is also connected through a capacitor 406 to a ground to which the source terminal 403 is also connected.

FIG. 4b is a cross sectional view of the semiconductor device illustrating how the device 400 of FIG. 4a can be implemented. FIG. 4c is an alternate schematic illustration of the structure of FIG. 4b to more clearly show how the circuit 400 of FIG. 4a is formed by the structure of FIG. 4b.

Referring to FIG. 4b, the field effect transistor 401 is fabricated by methods well known to those skilled in the art on a semiconductor chip. The field effect transistor may be just one element of a complex integrated circuit on the chip. Only the field effect transistor need be illustrated as an exemplary active circuit element. The drain terminal 402, the source terminal 403, and the gate terminal 404 of the transistor 401 are formed on the bottom surface of the chip 401. The drain, the source, and the gate terminals of the transistor are bonded to respective bond pads 440, 441, 442 on a top interconnect layer 411 of the signal connection substrate 410 by connectors 443, 444, 445, respectively. The connectors 443, 444, 445 may be deformable bumps or other electrical connectors as described above in conjunction with FIG. 3. In this specific implementation, no interconnections are made within the signal connection substrate 410. Signals communicated from the three terminals 402, 403 and 404 of the field effect transistor 401 pass from the top interconnect layer 411 of the signal connection substrate 410, by way of three separate through-hole connections 421, 422 and 423 through the wafer, to the bottom interconnect layer 412. Bond pads 446, 447 on the top interconnect layer 411 are unused in this example but form part of the identical pattern of bond pads on the interconnect layer 412.

In the specific implementation of FIG. 4b, a thin film capacitor substrate 419 is mounted below the signal connection substrate 410. A top interconnect layer 413 on the top surface of the capacitor substrate 419 has a plurality of bond pads 431, 457, 456, 455, 454 arranged in a pattern identical to the pattern of a plurality of bond pads 459, 460, 432, 461, 462, respectively, on a bottom interconnect layer 414 mounted on the bottom surface of the capacitor substrate 419. The identicalness of the bond pads on the interconnect layers is described

above. In addition, the top interconnect layer 413 of the capacitor substrate 419 is identical to the top interconnect layer 411 and the bottom interconnect layer 412 of the signal connection substrate layer.

Bond pads 448, 449, 450, 451, 452 on the bottom interconnect layer 412 are bonded to the respective bond pads 431, 457, 456, 455, 454 on the top interconnect layer 413 by respective connectors 463, 424, 425, 426, 453. Electrical signals are communicated between the terminals 402, 403, 404 of the transistor 401 and the respective bond pads 455, 457, 456 on the top interconnect layer 413. It should be noted that although the bond pads 424, 452, 454 are unused by the circuit, they are nonetheless connected to the corresponding bond pad in the adjacent interconnect layer.

Within the thin film capacitor substrate 419, a plurality of capacitors 406 are formed in a thin film layer, although only one of these capacitors is shown for reason of clarity. The capacitor 406 is shown as a lumped circuit element for simplicity. The capacitor 406 typically comprises two parallel spaced apart layers of metal with a dielectric layer sandwiched between the two metal layers. The gate 404, which is coupled to the bond pad 456, is connected to one terminal of a capacitor 406. The other terminal of the capacitor 406 is connected to the bond pad 431. Thus a signal path is formed from the gate 404 to the bond pad 456 and running through the capacitor 406 to the bond pad 431.

From the bond pad 431, the signal path of the gate passes through the capacitor substrate 419 by way of a through-hole connection 430 to a bond pad 459 on the bottom interconnect layer 414 which is mounted on the bottom surface of the capacitor substrate 419. The signal path continues through a connector 493 to a bond pad 458 in a top interconnect layer 415 of the resistor substrate 420. From the bond pad 458, the signal path passes through the resistor substrate 410 by way of a through hole connection 435 to a bond pad 464 in a bottom interconnect layer 420 on the bottom surface of the resistor substrate. The signal path continues through a connector 465 to a bond pad 466 on a top interconnect layer 417 on the top surface of the power supply substrate 421, where it is connected to ground. Connection to ground may be accomplished through a top interconnect layer having signal lines that connect to an external ground, or as in more complicated circuits, to a circuit fabricated within the power supply substrate 421.

The gate signal at the bond pad 456 is also connected by way of a through-hole connection 428 to a bond pad 432 on the bottom interconnect layer 414 of the capacitor substrate 419 where it is bonded to a bond pad 433 of the resistor substrate 420 by a connector 467.

Within the thin film resistor substrate 420, a plurality of resistors 405 are formed in a thin film layer, although only one of these resistors is shown for reason of clarity. Consequently, the signals from the gate 404 are translated through the signal connect substrate 410 and the

capacitor substrate 419 on through-hole connections 422, 428, respectively, to the bond pad 433. A first terminal of the resistor 405 fabricated within the thin film layer is connected to the bond pad 433. A second terminal of the resistor 405 is connected to a bond pad 434 on the top interconnect layer 415. Thus a signal path is formed from the gate 404 to bond pads 425 and 433 successively, running through the resistor 405 to the bond pad 434. Although not functionally used, a bond pad 462 in the bottom interconnect layer 414 is connected by a connector 481 to the bond pad 434.

From the bond pad 434, this signal from the gate 404 is connected, by way of a through-hole connection 436, and a bond pad 468 to a bond pad 469 by a connector 470. The bond pad 469 is connected to the power supply VCC (not shown) in the power supply substrate 421. Connection to the power supply VCC may also be accomplished through a top interconnect layer having signal lines that connect to an external power supply VCC.

The source terminal 403 from the chip 401 is bonded by a connector 444 to the bond pad 441 on the top interconnect layer 417 of the signal connection substrate 410. From the source terminal 403 the source signal passes through the connector 444 to the bond pad 441 on the top interconnection layer 411. From the bond pad 441 the source signal passes through the signal connection substrate 410 along a through-hole connection 423 to a bond pad 449 on the bottom interconnect layer 412. From the bond pad 449 the signal passes through a connector 424 to a bond pad 457 on the top interconnect layer 413 of the capacitor substrate 419. The source signal passes through the capacitor substrate 419 through the through-hole connection 429 to a bond pad 460 on the bottom interconnect layer 414. The source signal continues from the bond pad 460 through a connector 471 to a bond pad 472 on the top interconnect layer 415 of the resistor substrate 420. The source signal passes through the resistor substrate 420 along a through-hole connection 437 and a bond pad 473 on the bottom interconnect layer 416 where it is transferred through a connector 474 to a bond pad 475 on the top interconnect layer 417 of the power substrate 421. The bond pad 475 is connected to ground. Connection to ground may also be accomplished through a top interconnect layer having signal lines that connect to an external ground.

In a manner similar to that described above for the source terminal 403, the signals from the drain terminal 402 passes through the signal connection substrate 410 along a through-hole connection 421 to a bond pad 450 on the bottom interconnect layer 412. From the bond pad 451 the signal passes through connector 426 to a bond pad 455 on the top interconnect layer 413 of the capacitor substrate 419. From the bond pad 455 the drain signal passes along a through-hole connection 427 to the bond pad 461 on the bottom interconnect layer 414 of the capacitor substrate 419. From the bond

pad 461 the signal passes through a connector 476 to a bond pad 477 on the top interconnect layer 415 of the resistor substrate 420. From the bond pad 477 a signal passes through the resistor substrate 420 along a through-hole connection 438 to a bond pad 478 on the bottom interconnect layer 416 of the resistor substrate 420. From the bond pad 478 the drain signal passes through a connector 479 to a bond pad 480 in the top interconnect layer 417 of the power substrate 421 where it is connected to the power supply VCC. As described above for connecting the resistor 405 to VCC, connection to the power supply VCC may also be accomplished through a top interconnect layer having signal lines that connect to an external power supply VCC.

The bond pads in the interconnect layers are arranged in an identical pattern, in particular, bond pads 446, 441, 442, 440, 447 in the top interconnect layer 411, the bond pads 448, 449, 450, 451, 452 on the bottom interconnect layer 412 are arranged in an identical pattern. Similarly, the bond pads in the top interconnect layer 413, the bottom interconnect layer 414, the top interconnect layer 415, the bottom interconnect layer 416 and the top interconnect layer 417 are also arranged in an identical pattern to those of the top interconnect layer 411. Because of the identical nature of interconnecting the substrates, the connectors 463, 453, 481, 483 are used to connect adjacent bond pads even though these pads are not electrically used. In particular, the connector 483 connects corresponding bond pad 482 and the bottom interconnect layer 416 of the resistor substrate 420 to a corresponding bond pad 480 in the top interconnect layer 417 of the power substrate 421. These bond pads and the corresponding connector are not electrically connected to any portion of the circuit in this example.

FIG. 4c shows how the gate signal travels via the signal connection substrate 410 to the capacitor substrate 419, where it is connected to a first terminal of a capacitor 406, and how a second terminal of the capacitor 406 is connected to ground. FIG. 4c also shows how the gate signal travels to the resistor substrate 420, where it is connected to one end of a resistor 405, and how the other end of the resistor 405 is connected to the power supply VCC. FIG. 4c also shows how the source signal from the transistor 401 travels through the signal connection substrate 410, the capacitor substrate 419 and the resistor substrate 420, bypassing the resistor 405, until it is connected to the power supply VCC. FIG. 4c also shows how the drain from the transistor travels through the signal connection substrate 410, the capacitor substrate 419, bypassing the capacitor 406, and the resistor substrate 420 until it is connected to ground.

Since the signal connection substrate 410 does not provide interconnections between bond pads that are not opposite each other on the substrate in the above embodiment, it can be eliminated from this specific implementation without altering the top interconnect layer of the capacitor substrate and with no difference in the

circuit (except shorter signal lengths). However, in other implementations, the signal connection substrate 410 can be used to provide connections to other chips, or different I/O pins of the same chip, or translation to bond pads that are not opposite.

The interconnect layers 411, 412, 413, 414, 415, 416 and 417 are shown in FIG. 4b to have identical patterns of bond pads. FIG. 7 is a top view showing an example of such patterns. Any one of very many spatial distributions of bond pads may be used, the patterns on each substrate being identical.

FIG. 4d is a cross sectional view of a device in which the capacitor substrate 419 and the resistor substrate 420 are interchanged from that of the device shown in FIG. 4b. In this implementation, the resistor substrate is closer to the field effect transistor 401 than the capacitor substrate. Schematically, however, the circuit of FIG. 4d is identical to the circuit of FIG. 4b which is shown in the schematic diagram of FIG. 4a. The resistor substrate of FIG. 4d is identical to that of FIG. 4b except it has a through-hole connection 490 between the bond pad 433 on the top layer and the bond pad 482 on the bottom interconnection layer. Similarly, the capacitor substrate is identical to that of FIG. 4b except that it has a through-hole connection 491 between the bond pad 454 on the top interconnect layer 413 and the bond pad 462 on the bottom interconnect layer 414 of the capacitor substrate. However, because the interconnection layers are identical, no changes are required to the pattern of bond pads.

FIG. 4e is an alternate schematic illustration of the structure of FIG. 4d to more clearly show how the circuit 400 of FIG. 4a is formed by the structure of FIG. 4d. FIG. 4e shows how the gate terminal 402 is connected via the signal connection substrate 410 to the capacitor substrate 420 where it is connected to a first terminal of the resistor 405 and is connected through the resistor substrate 420 to the capacitor substrate where it is connected to a first terminal of the capacitor 406. FIG. 4e also shows how the drain terminal 402 is connected via the signal connector substrate 410, the resistor substrate 420, and the capacitor substrate 419 to the power supply VCC in the power substrate 421. FIG. 4e also shows how the source terminal 403 is similarly connected via the signal connector substrate 410, the resistor substrate 420, and the capacitor substrate 419 to ground in the power substrate 421.

FIG. 5 is a flow chart illustrating how the present invention can accelerate manufacturing of a semiconductor device. Steps 501, 502, 503 and 504 depict the different thin film functional substrates (TFS1 and TFS2) and the power supply substrate, being manufactured in parallel with the manufacturing of semiconductor chip (s). Steps 505, 506, 507 and 508 depict the different functional substrates and chips being tested in parallel with the testing of the power supply substrate and the semiconductor chip. In step 509, the functional substrates, including the power substrate are assembled to

form a carrier. Thereafter in step 510, the assembled carrier is retested. Upon satisfactory passing of the test in step 510, the chip(s) are then placed onto and attached to the carrier. To form the final device, a plurality of carriers are mounted to an interconnection substrate (see below).

As the substrates and the chips are manufactured and tested in parallel, manufacturing time of a device is reduced. More significantly, by testing the chip(s) and substrates individually before final assembly thereof into a device, overall yield of the manufacturing process is increased.

FIG. 7 is a top plan view showing a fully populated multi-chip module (MCM) according to principles of the invention.

FIG. 8 is a cross-sectional view of the MCM taken along line 9-9 of FIG. 7 showing integrated circuit elements constructed according to principles of the invention.

A multi-chip module 800 comprises a multi-layer interconnection substrate 802 having a plurality of signal traces 804, 806 (shown in FIG. 8) for communicating electrical signals between integrated circuit elements. Although the signal traces 804, 806 are shown as ground and power respectively for the interconnection substrate 802, this is for illustrative purposes only. The traces may also carry other electrical signals, such as clocks, control signals, address buses or data buses. The interconnection substrate 802 preferably comprises a multi-layer ceramic dielectric body portion having electrical interconnects for translating electric signals. Alternatively, the interconnection substrate comprises a printed wiring board. A connector interface 807 is on the top surface of the interconnection substrate 802. The connector interface 807 has a plurality of pads (not shown) for electrically interfacing with an external connector.

Each integrated circuit element 808 comprises a chip and a plurality of functional substrates assembled together to form a carrier as described above. A connector pad region has a plurality of bond pads for coupling to a connector (not shown) for communicating electrical signals between the multi-chip module and an external electronic device such as other multi-chip modules, computer keyboards, terminals, printers, disks and other input/output devices or interfaces. Although six integrated circuit elements are shown in FIG. 7, the invention is not so limited. The integrated circuits are typically processor devices, such as gate array processors, or memory devices.

Referring now to FIG. 8, three integrated circuit 808 elements are illustrated. Each integrated circuit element comprises a semiconductor chip 810 and a plurality of functional substrates 812. A first integrated circuit element 808-1 has a resistor substrate 812-1 mounted to a first portion of the top surface of the interconnection substrate 802. A capacitor substrate 812-2 is mounted to the top surface of the resistor substrate 812-1. A sem-

iconductor chip 810 is mounted to the top surface of the capacitor substrate 812-2. A second integrated circuit element 808-2 has a capacitor substrate 812-2 mounted to the top surface of the interconnection substrate 802 in contrast to the first integrated circuit element 808-1 which has a resistor substrate 812-1 mounted to the interconnection substrate 802. The second integrated circuit element 808-2 has a resistor substrate 812-1 mounted on a second portion of the top surface of the capacitor substrate 812-2. A semiconductor chip 810 is mounted to the top surface of the resistor substrate 812-1. A third integrated circuit element 808-3 has one substrate layer, a capacitor substrate 812-2, mounted to a third portion of the top surface of the interconnection substrate 802 and a semiconductor chip 810 mounted on the top surface of the capacitor substrate 812-2. Interconnections between the bond pads of the semiconductor chips and the substrate layers are not shown in FIG. 8 for simplicity and clarity. These interconnections are formed as described above in connection with FIGS. 3-4.

By employing an identical interconnect layer having an identical grid of bond pads, the substrate layers of the integrated circuits may be interchanged without the necessity of redesigning the interconnect layer, although the interconnections within the substrate may need to be redesigned or modified for assembling different circuits.

The description of the particular embodiment is given above for the understanding of the present invention. It will be understood that various modifications and additions can be made without substantially departing from the scope of the present invention as defined by the claims.

Claims

1. A multi-chip module (800), comprising:

a multi-layer interconnection substrate (802) carrying a plurality of integrated circuit elements (808) disposed thereon, wherein the multi-layer interconnection substrate (802) comprises a plurality of interconnection traces (804, 806) to communicate electrical signals between said integrated circuit elements (808), where each integrated circuit element (808) comprises:

a first functional substrate (812-1) having a bottom and a top interconnect layer, the bottom interconnect layer being coupled to the interconnection substrate (802), said first functional substrate (812-1) having a single type of passive electrical functional elements; and
at least one second functional substrate

(812-2) stacked successively on said first functional substrate (812-1), each having a bottom and a top interconnect layer, the lowermost second functional substrate (812-2) having its bottom interconnect layer coupled to the top interconnect layer of said first functional substrate (812-1), and the uppermost second functional substrate (812-2) having its top interconnect layer coupled to at least one semiconductor chip (810), each second functional substrate having a single type of passive electrical functional elements, and wherein integrated circuits of the semiconductor chip (810) are in electrical contact with the passive electrical functional elements of the first and each second functional substrate (812-1, 812-2);

wherein the passive electrical functional elements in the first and each second functional substrate (812-1, 812-2) are selected from the group consisting of electrical signal conductors, capacitors, and resistors;

wherein the top and bottom interconnect layers of the first and each second functional substrate (812-1, 812-2) have identical patterns of electrical contacts; and

wherein the first and second functional substrates (812-1, 812-2) each comprise through-hole connectors extending therethrough that are filled with conductive vias, the conductive vias interconnecting the top and bottom interconnect layers of the first and each second functional substrate (812-1, 812-2) and providing connection with the passive electrical functional elements within the first and each second functional substrate (812-1, 812-2).

2. A process for forming a multi-chip module (800) comprising the steps of:

forming a multi-layer interconnection substrate (802) for carrying a plurality of integrated circuit elements (808), the interconnection substrate (802) having a top interconnect layer, and having a plurality of interconnection traces (804, 806) to communicate electrical signals between said integrated circuit elements; forming each integrated circuit element (808) by:

forming a first functional substrate (812-1) having a single type of passive electrical functional elements, the first functional substrate (812-1) having a bottom and a top interconnect layer; forming at least one second functional sub-

strate (812-2) each having a single type of passive electrical functional elements, each second functional substrate (812-2) having a bottom and a top interconnect layer, wherein the top and bottom interconnect layers for the first and second functional substrates (812-1, 812-2) are formed by using the same metallurgy, design rules, and fabrication processes, wherein each first and second functional substrate (812-1, 812-2) comprises through-hole connectors extending therethrough that are filled with conductive vias, the conductive vias interconnecting the top and bottom interconnect layers of the first and each second substrate (812-1, 812-2) and providing connection between the passive electrical functional elements in the first and each second substrate, wherein the top and bottom interconnect layer for the first and each second substrate (812-1, 812-2) have identical patterns of electrical contacts, and wherein the passive electrical functional elements in the first and each second substrate (812-1, 812-2) are selected from the group consisting of electrical signal conductors, capacitors, and resistors;

stacking one said second functional substrate (812-2) on said first substrate (812-1) so that the electrical contacts of the bottom interconnect layer of one said second functional substrate (812-2) are connected with the electrical contacts of the top interconnect layer of the first functional substrate; and

stacking a semiconductor chip (810) on one said second functional substrate (812-2) so that the chip is connected to the electrical contacts of the top interconnect layer of one said second functional substrate (812-2);

and mounting the first functional substrate (812-1) onto the interconnection substrate (802) so that the electrical contacts of the bottom interconnect layer of the first functional substrate (812-1) are connected to electrical contacts of the top interconnect layer of the interconnection substrate (802), wherein the first and second functional substrates (812-1, 812-2) are formed separately and tested before being stacked together and mounted onto the interconnection substrate.

Patentansprüche

1. Vielfach-Chip-Modul (800), mit:

einem Vielfachschicht-Verbindungs-
substrat (802), welches eine Vielzahl von integrierten
Schaltungselementen (808) trägt, die darauf
angeordnet sind, wobei das Vielfachschicht-
Verbindungssubstrat (802) eine Vielzahl von
Verbindungsleiterbahnen (804, 806) enthält,
um elektrische Signale zwischen den integrier-
ten Schaltungselementen (808) zu übertragen,
wobei jedes integrierte Schaltungselement
(808) folgendes aufweist:

ein erstes Funktionssubstrat (812-1) mit ei-
ner Boden- und einer oberen Verbindungs-
schicht, wobei die Bodenverbindungsschicht
mit dem Verbindungssubstrat (802) gekoppelt
ist und das erste Funktionssubstrat (812-1)
einen einzelnen Typ von passiven elektrischen
Funktionselementen besitzt; und
wenigstens ein zweites Funktionssubstrat
(812-2), welches aufeinanderfolgend auf
dem ersten Funktionssubstrat (812-1) auf-
gestapelt ist und wobei jedes eine Boden-
und eine obere Verbindungsschicht be-
sitzt, wobei das unterste zweite Funktions-
substrat (812-2) eine Bodenverbindungsschicht
besitzt, die mit der oberen Verbindungsschicht
des ersten Funktionssubstrats (812-1) gekoppelt
ist, und wobei das oberste zweite Funktionssubstrat
(812-2) eine obere Verbindungsschicht besitzt,
die mit wenigstens einem Halbleiterchip (810)
gekoppelt ist, wobei jedes zweite Funktionssubstrat
einen einzelnen Typ von passiven elektrischen
Funktionselementen besitzt und wobei die integrierten
Schaltungen des Halbleiterchips (810) in elektri-
ischem Kontakt mit den passiven elektrischen
Funktionselementen des ersten und jedes zweiten
Funktionssubstrats (812-1, 812-2) stehen;

wobei die passiven elektrischen Funktionselemente
in dem ersten und in jedem zweiten Funktionssubstrat
(812-1, 812-2) ausgewählt sind aus der Gruppe, die
besteht aus elektrischen Signalleitern, Kondensatoren
und Widerständen;
die oberen und Bodenverbindungsschichten des ersten
und jedes zweiten Funktionssubstrats (812-1, 812-2)
identische Muster von elektrischen Kontakten be-
sitzen; und
wobei das erste und das zweite Funktionssubstrat
(812-1, 812-2) jeweils Durchgangsloch-

verbinder aufweisen, die sich durch dieses hin-
durch erstrecken und die mit leitenden Durchgangs-
kontaktierungen gefüllt sind, wobei die leitenden
Durchgangskontaktierungen die obere und die Boden-
verbindungsschichten des ersten und jedes zweiten
Funktionssubstrats (812-1, 812-2) verbinden und eine
Verbindung mit dem passiven elektrischen Funktionselement
innerhalb des ersten und jedes zweiten Funktionssubstrats
(812-1, 812-2) erzeugen.

2. Verfahren zur Herstellung eines Vielfach-Chip-Moduls (800), mit den folgenden Schritten:

Ausbilden eines Vielfachschicht-Verbindungs-
substrats (802) zum Tragen einer Vielzahl von
integrierten Schaltungselementen (808), wobei
das Verbindungssubstrat (802) eine obere Ver-
bindungsschicht besitzt, und eine Vielzahl von
Verbindungsbahnen oder Spuren (804, 806)
aufweist, um elektrische Signale zwischen den
integrierten Schaltungselementen zu übertra-
gen;
Ausbilden von jedem integrierten Schaltungs-
element (808) durch:

Ausbilden eines ersten Funktionssubstrats
(812-1) mit einem einzelnen Typ von passiven
elektrischen Funktionselementen, wobei das erste
Funktionssubstrat (812-1) eine Boden- und eine obere
Verbindungsschicht aufweist;
Ausbilden von wenigstens einem zweiten
Funktionssubstrat (812-2), wobei jedes
Substrat einen einzelnen Typ von passiven
elektrischen Funktionselementen besitzt, jedes
zweite Funktionssubstrat (812-2) eine Boden- und
eine obere Verbindungsschicht besitzt, wobei die obere
und die Bodenverbindungsschichten für das erste
und das zweite Funktionssubstrat (812-1, 812-2)
durch Anwendung der gleichen Metallurgie, Konstruktions-
regeln und Fabrikationsprozesse hergestellt sind und
wobei jedes erste und zweite Funktionssubstrat
(812-1, 812-2) Durchgangslochverbinder aufweist,
die sich durch dasselbe hindurch erstrecken, die mit
leitenden Durchkontaktierungen gefüllt sind, wobei die
leitenden Durchkontaktierungen die oberen und die
Bodenverbindungsschichten des ersten und jedes
zweiten Substrats (812-1, 812-2) miteinander verbin-
den und auch eine Verbindung zwischen den passiven
elektrischen Funktionselementen in dem ersten und
jedem zweiten Substrat schaffen, die obere und die
Bodenverbindungsschicht für das erste und jedes
zweite Sub-

strat (812-1, 812-2) identische Muster von elektrischen Kontakten aufweisen und wobei die passiven elektrischen Funktionselemente in dem ersten und jedem zweiten Substrat (812-1, 812-2) ausgewählt sind aus der Gruppe, bestehend aus elektrischen Signalleitern, Kondensatoren und Widerständen; 5

Übereinanderstapeln von einem der zweiten Funktionssubstrate (812-2) auf dem ersten Substrat (812-1), so daß die elektrischen Kontakte der Bodenverbindingsschicht von einem der zweiten Funktionssubstrate (812-2) mit den elektrischen Kontakten der oberen Verbindungsschicht des ersten Funktionssubstrats verbunden werden; und 10

Aufstapeln eines zweiten Chips (810) auf einem der zweiten Funktionssubstrate (812-2), so daß der Chip mit den elektrischen Kontakten der oberen Verbindungsschicht von einem der zweiten Funktionssubstrate (812-2) verbunden wird; und 20

Montieren des ersten Funktionssubstrats (812-1) auf dem Verbindungssubstrat (802), so daß die elektrischen Kontakte der Bodenverbindingsschicht des ersten Funktionssubstrats (812-1) mit den elektrischen Kontakten der obersten Verbindungsschicht des Verbindungssubstrats (802) verbunden werden, wobei die ersten und zweiten Funktionssubstrate (812-1, 812-2) getrennt hergestellt und getestet werden, bevor sie miteinander gestapelt und auf dem Verbindungssubstrat montiert werden. 30 35

Revendications

1. Module multi-puce (800), comprenant : 40

un substrat d'interconnexion multicouche (802) portant une pluralité d'éléments de circuit intégrés (808) disposés sur celui-ci, où le substrat d'interconnexion multicouche (802) comprend une pluralité de pistes d'interconnexion (804, 806) pour communiquer des signaux électriques entre ledit élément de circuit intégré (808), où chaque élément de circuit intégré (808) comprend : 45 50

un premier substrat fonctionnel (812-1) ayant une couche d'interconnexion inférieure et supérieure, la couche d'interconnexion inférieure étant couplée au substrat d'interconnexion (802), ledit premier substrat fonctionnel (812-1) ayant un type unique d'éléments fonctionnels électriques 55

passifs ; et au moins un second substrat fonctionnel (812-2) empilé successivement sur ledit premier substrat fonctionnel (812-1), chacun ayant une couche d'interconnexion inférieure et supérieure, et le second substrat fonctionnel le plus inférieur (812-2) ayant sa couche d'interconnexion inférieure couplée à la couche d'interconnexion supérieure dudit premier substrat fonctionnel (812-1), et le second substrat fonctionnel le plus supérieur (812-2) ayant sa couche d'interconnexion supérieure couplée à au moins une puce semi-conductrice (810), chaque second substrat fonctionnel ayant un type unique d'éléments fonctionnels électriques passifs, et dans lequel des circuits intégrés de la puce semi-conductrice (810) sont en contact électrique avec les éléments fonctionnels électriques passifs du premier et de chaque second substrat fonctionnel (812-1, 812-2) ;

dans lequel les éléments fonctionnels électriques passifs dans le premier et chaque second substrat fonctionnel (812-1, 812-2) sont sélectionnés à partir du groupe se composant des conducteurs de signaux électriques, de condensateurs et de résistances ;

dans lequel les couches d'interconnexion supérieures et inférieures du premier et de chaque second substrat fonctionnel (812-1, 812-2) ont des motifs identiques de contacts électriques ; et

dans lequel les premier et second substrats fonctionnels (812-1, 812-2) comprennent chacun des connecteurs à trou traversant s'étendant à travers ceux-ci qui sont remplis avec des vias conducteurs, les vias conducteurs reliant les couches d'interconnexion supérieures et inférieures du premier et de chaque second substrat fonctionnel (812-1, 812-2) et fournissant une connexion avec les éléments fonctionnels électriques passifs dans le premier et chaque second substrat fonctionnel (812-1, 812-2).

2. Procédé de formation d'un module multi-puce (800) comprenant les étapes de : 50

formation d'un substrat d'interconnexion multicouche (802) pour réaliser une pluralité d'éléments de circuit intégrés (808), le substrat d'interconnexion (802) ayant une couche d'interconnexion supérieure, et ayant une pluralité de pistes d'interconnexion (804, 806) pour communiquer des signaux électriques entre lesdits éléments de circuit intégré ;

formation de chaque élément de circuit intégré (808) par :

formation d'un premier substrat fonctionnel (812-1) ayant un type unique d'éléments fonctionnels électriques passifs, le premier substrat fonctionnel (812-1) ayant une couche d'interconnexion inférieure et supérieure ; 5

formation d'au moins un second substrat fonctionnel (812-2) ayant chacun un type unique d'éléments fonctionnels électriques passifs, chaque second substrat fonctionnel (812-2) ayant une couche d'interconnexion inférieure et supérieure, dans lequel les couches d'interconnexion inférieures et supérieures pour les premier et second substrats fonctionnels (812-1, 812-2) sont formées en utilisant la même métallurgie, les mêmes règles de conception, et les mêmes traitements de fabrication, dans lequel chacun du premier et du second substrat fonctionnel (812-1, 812-2) comprend des connecteurs à trou traversant s'étendant à travers ceux-ci qui sont remplis avec des vias conducteurs, les vias conducteurs interconnectant les couches d'interconnexion supérieures et inférieures du premier et de chaque second substrat fonctionnel (812-1, 812-2) et fournissant une connexion entre les éléments fonctionnels électriques passifs dans le premier et chaque second substrat fonctionnel, où les couches d'interconnexion supérieure et inférieure pour le premier et chaque second substrat (812-1, 812-2) ont des motifs identiques de contacts électriques, et où les éléments fonctionnels électriques passifs dans le premier et chaque second substrat (812-1, 812-2) sont sélectionnés à partir du groupe se composant de conducteurs de signal électrique, de condensateurs et de résistances ; 10 15 20 25 30 35 40

empilement d'un dudit second substrat fonctionnel (812-2) sur ledit premier substrat (812-1) pour que les contacts électriques de la couche d'interconnexion inférieure d'un dudit second substrat fonctionnel (812-2) soient connectés avec les contacts électriques de la couche d'interconnexion supérieure du premier substrat fonctionnel ; et 45 50

empilement d'une puce semi-conductrice (810) sur un dudit second substrat fonctionnel (812-2) pour que la puce soit raccordée aux contacts électriques de la couche d'interconnexion supérieure d'un dudit second substrat fonctionnel (812-2) ; 55

et montage du premier substrat fonctionnel (812-1) sur le substrat d'interconnexion (802) pour que les contacts électriques de la couche d'interconnexion inférieure du premier substrat fonctionnel (812-1) soient raccordés aux contacts électriques de la couche d'interconnexion supérieure du substrat d'interconnexion (802), où les premier et second substrats fonctionnels (812-1, 812-2) sont formés séparément et testés avant d'être empilés ensemble et montés sur le substrat d'interconnexion.

Fig. 1

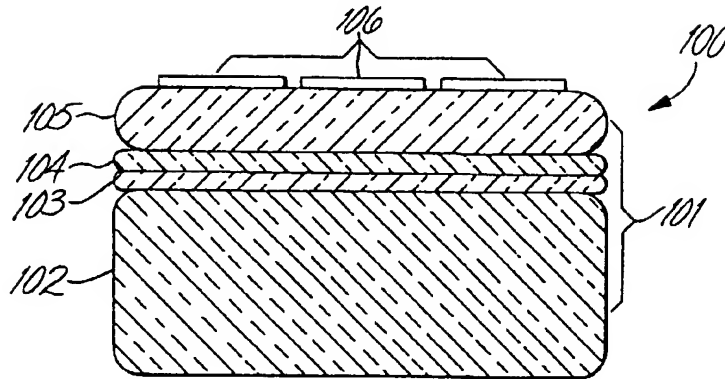


Fig. 2

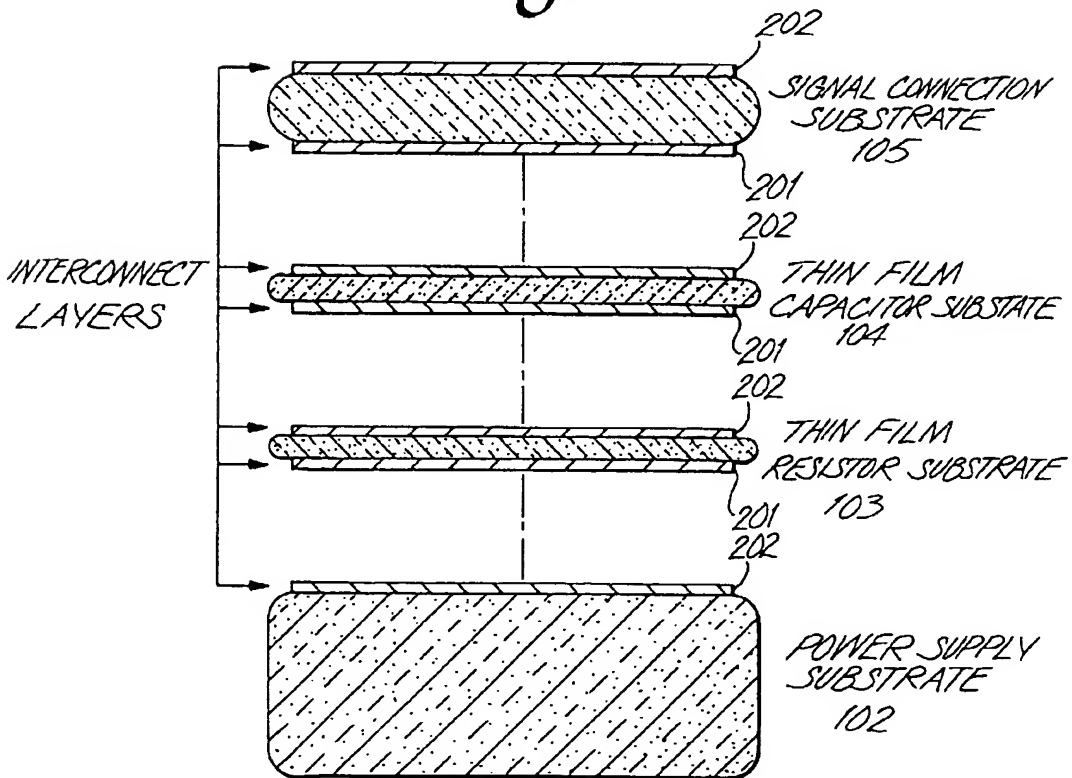


Fig. 3

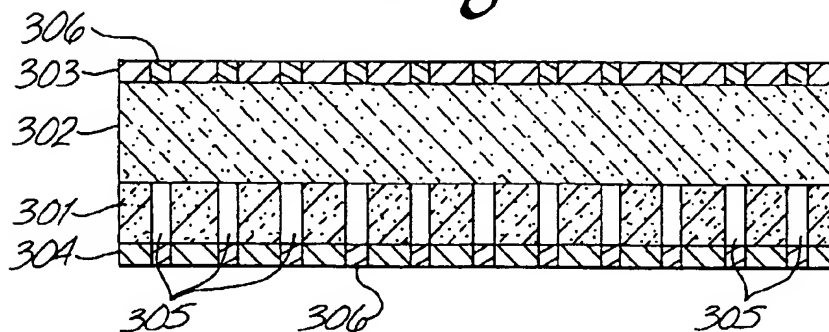


Fig. 5

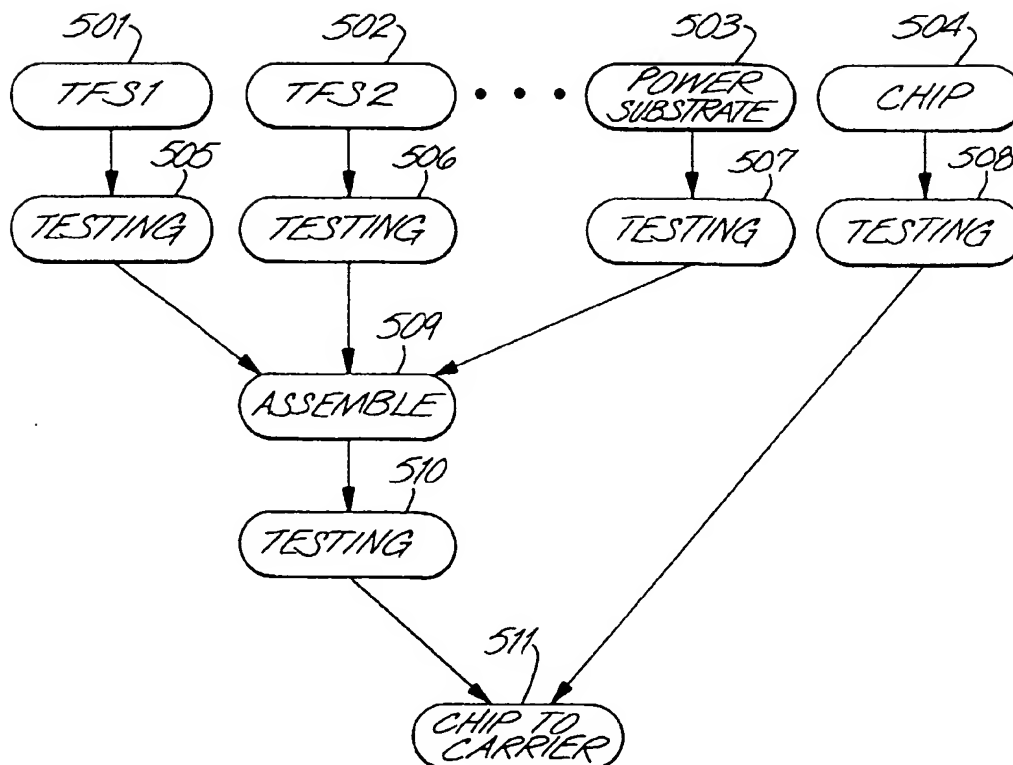


Fig. 4a

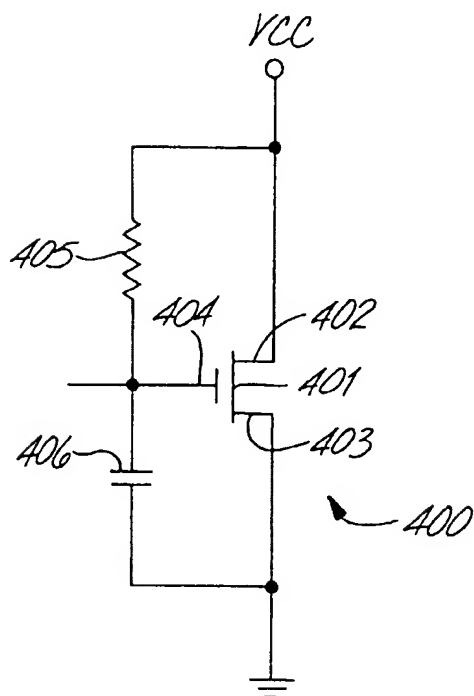


Fig. 6



Fig. 4b

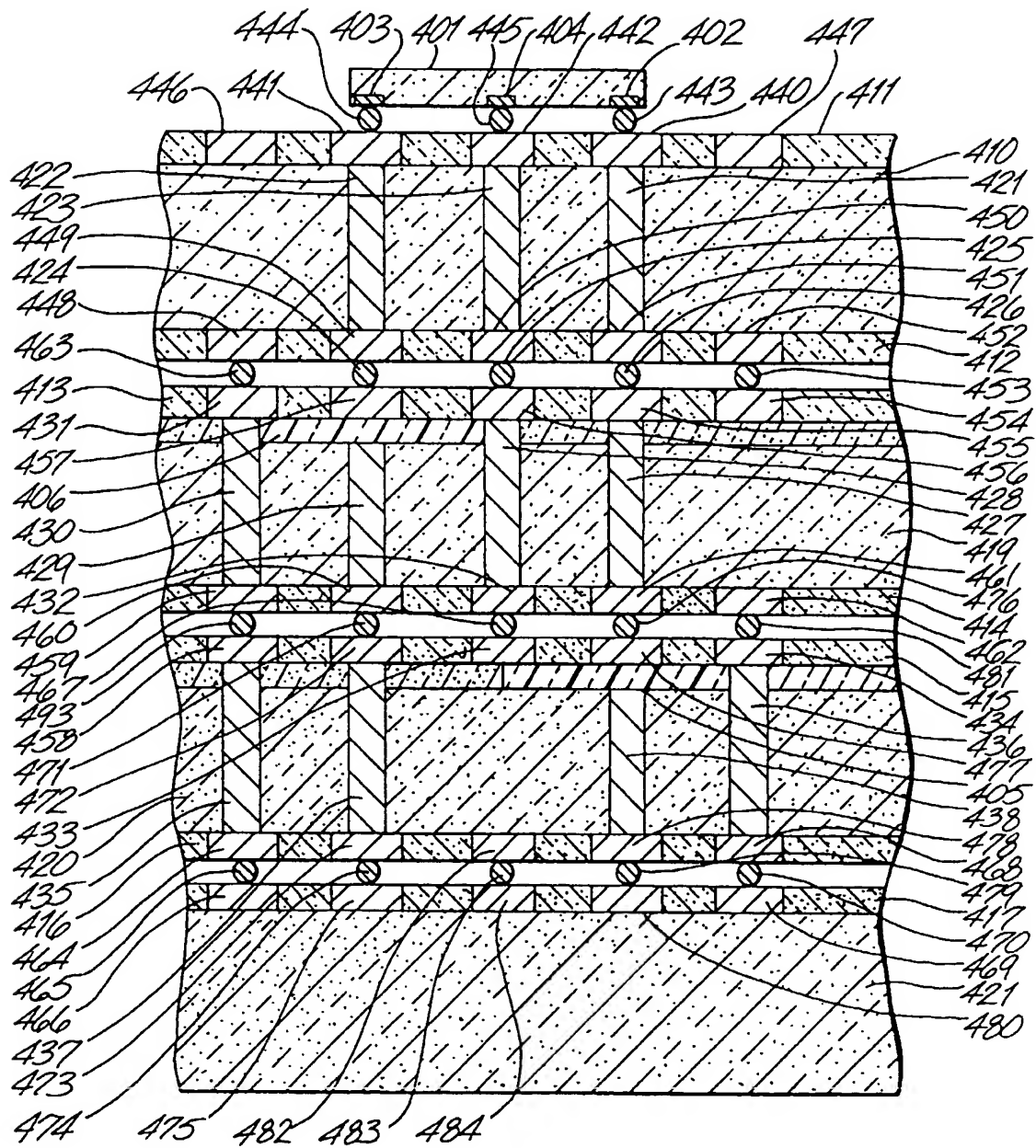


Fig. 4c

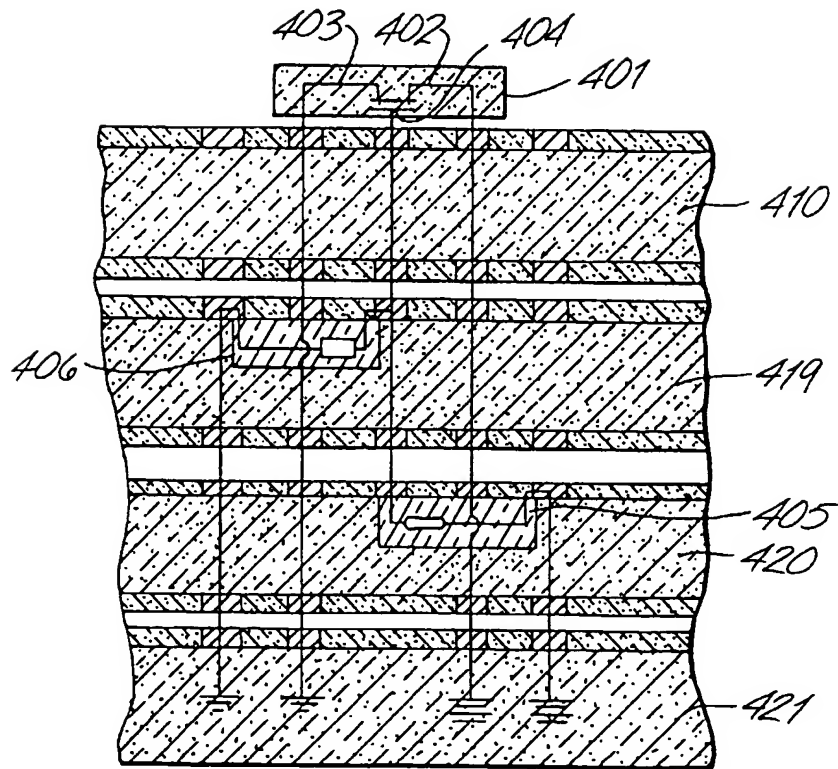


Fig. 4d

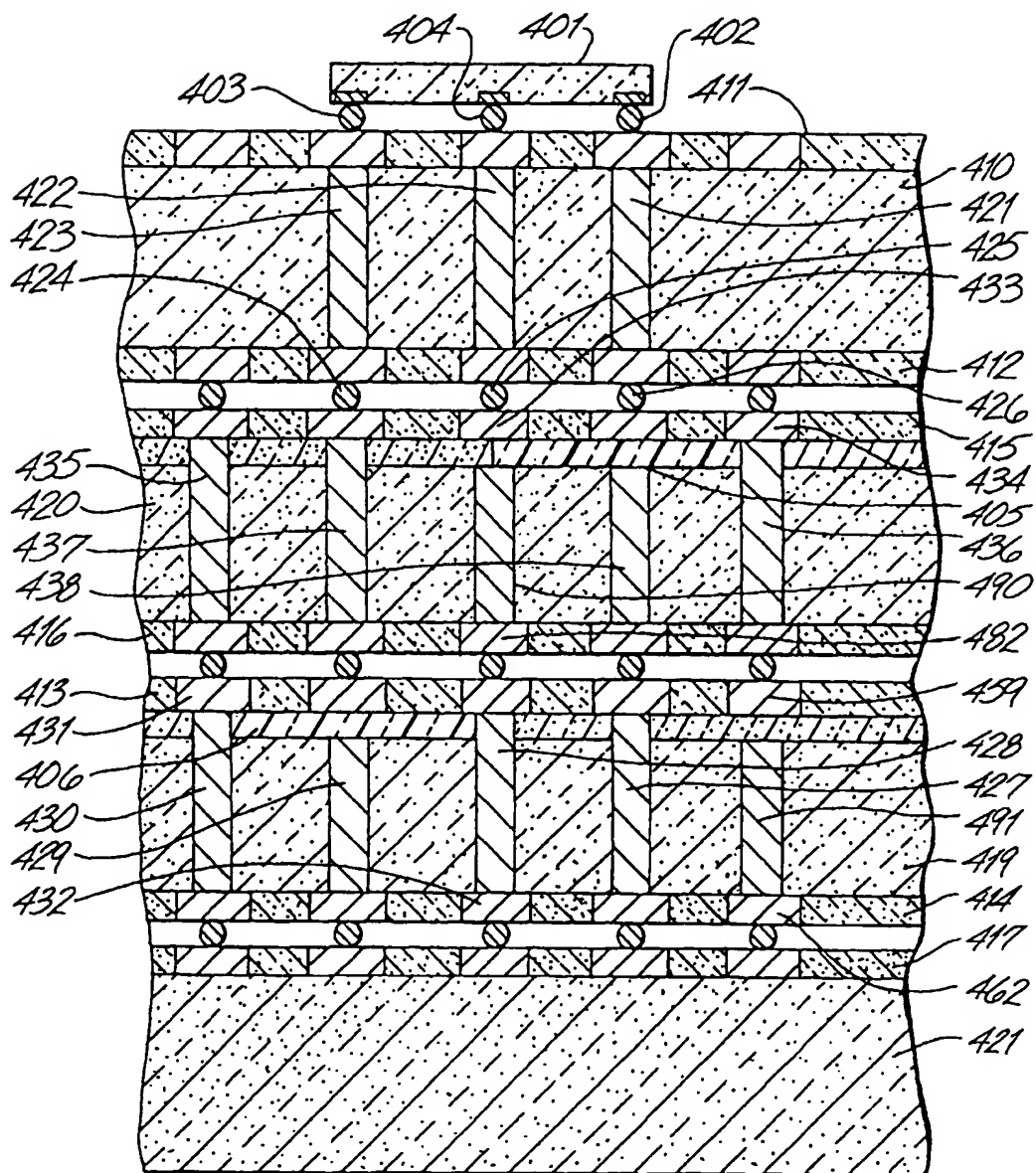


Fig. 4e

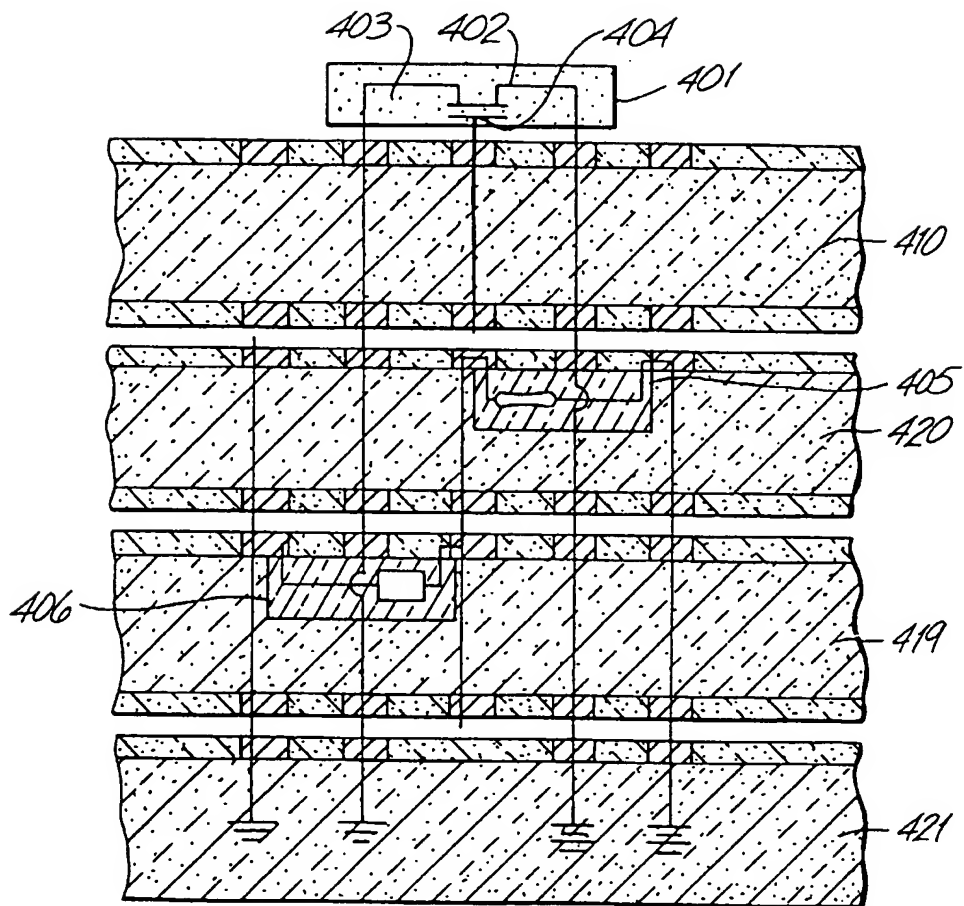


Fig. 7

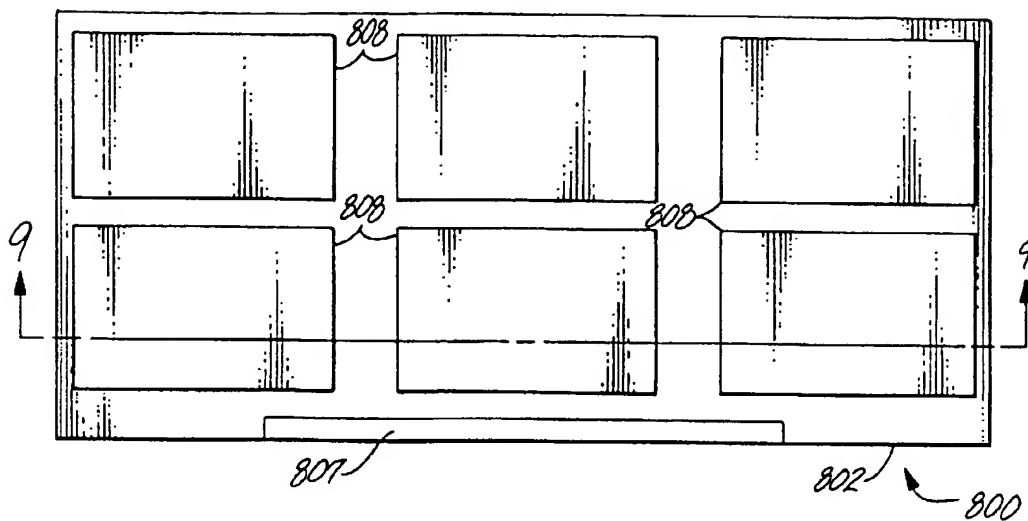


Fig. 8

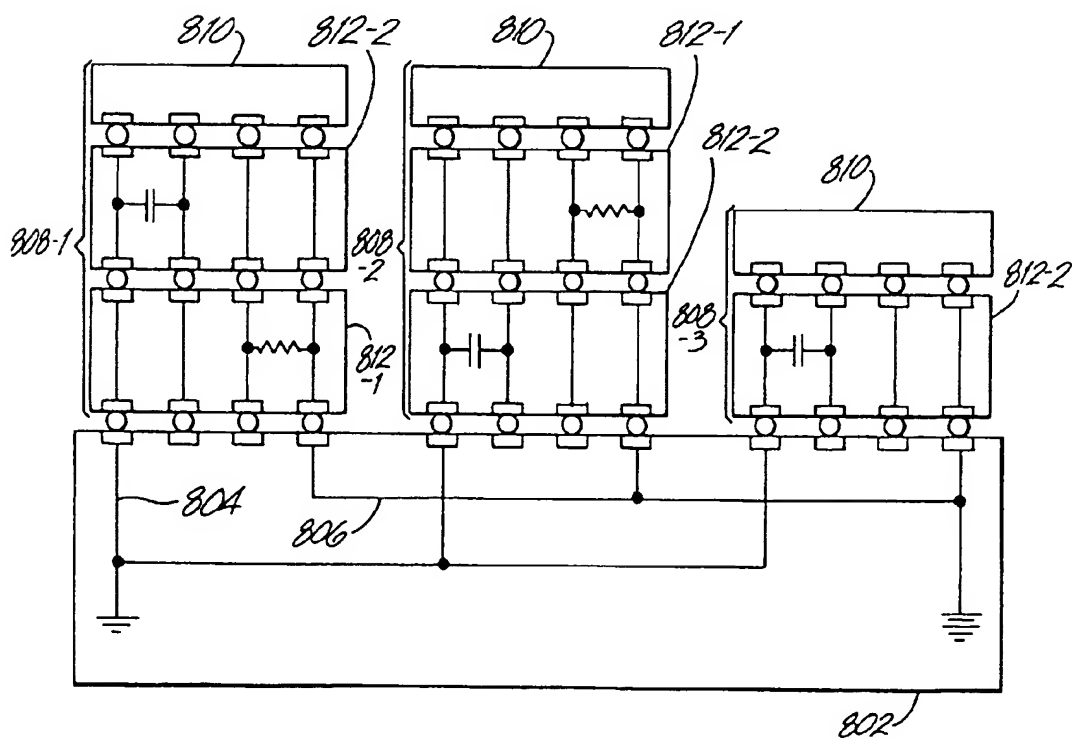
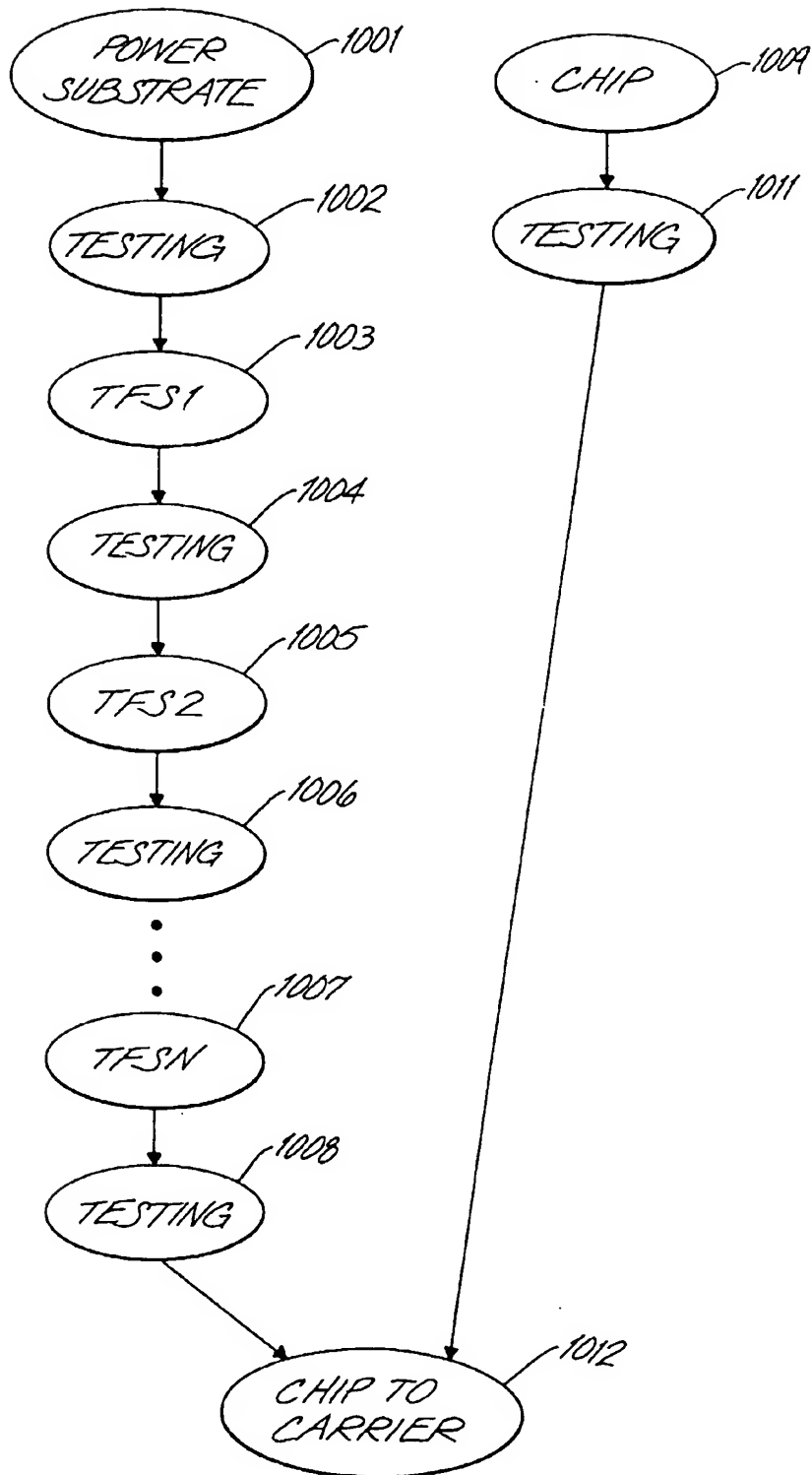


Fig. 9
PRIOR ART



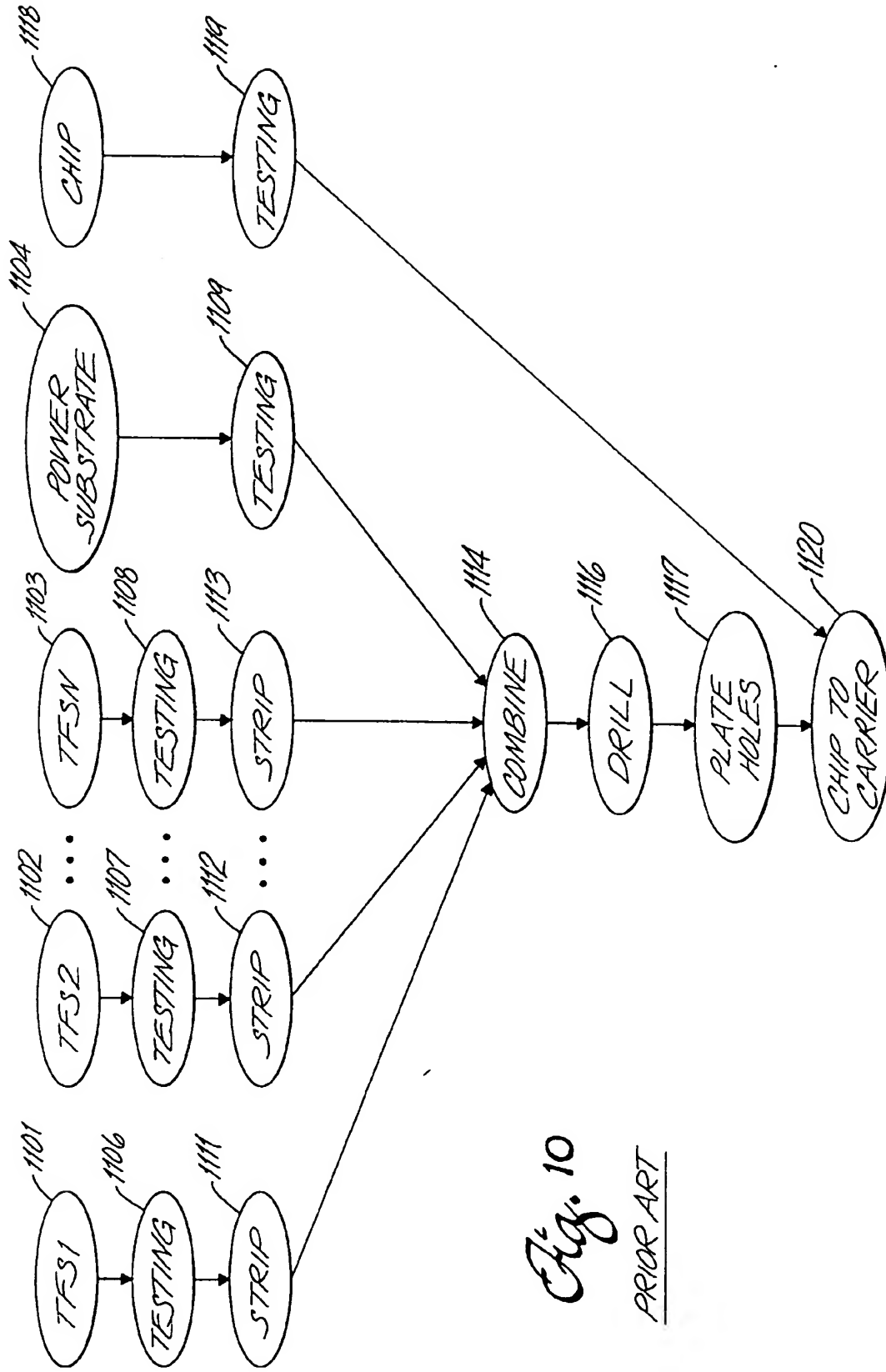


Fig. 10
PRIOR ART

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